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ABSTRACT

Since the popularization of networked computing that began in 1993, many excited educators have employed networked computers to improve motivation and learning in the classroom. Computers have also become a focal point for the improvement of instruction through the introduction of teaching methods that better support constructivist learning. While there is a growing consensus that computers can be an effective tool for talented teachers, little is known about the deeper effects of educational computing on children and their families when computer use is pervasive and family access at home is cost-free. This paper reports some of the results of a long-term study of families and students who have had immersive exposure to network-based educational computing in a constructivist classroom, starting in the 5th grade. (Author)

Immersive Educational Technology: Changing Families and Learning

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Presented at AERA, April 21, 1999, Montreal, CA

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Abstract

Since the popularization of networked computing that began in 1993, many excited educators have employed networked computers to improve motivation and learning in the classroom. Computers have also become a focal point for the improvement of instruction through the introduction of teaching methods that better support constructivist learning. While there is a growing consensus that computers can be an effective tool for talented teachers, little is known about the deeper effects of educational computing on children and their families when computer use is pervasive and family access at home is cost-free. This paper reports some of the results of a long-term study of families and students who have had immersive exposure to network-based educational computing in a constructivist classroom, starting in the 5th grade.

Introduction

The PCs for Families (PCF) project at Virginia Tech was initiated in 1996 to determine the long-term educational and social changes that would occur in children and within their families if they were given free and unlimited access to network-based computing both at home and at school. The literature on the beneficial effects of family involvement in education is large and convincing (Henderson, 1987). Considering the technical flexibility and the motivational strength of computers, they seemed an obvious vehicle for making significant changes in educational outcome through a broad intervention that reached from the classroom into the home. Above all, we wanted to eliminate access, cost, and training as obstacles to use by children and their families. The project is in a sense an educational analog of the Homenet Project (Kraut, *et al.* 1996, 1998) which they term an effort to "describe how ordinary citizens use the Internet and explore their motivations for doing so."

PCF was conceived by a master teacher and a computer scientist. The idea evolved from the excitement over the educational potential of networked computing and took shape over what then appeared to be insurmountable financial, organizational, and technical difficulties in applying and testing it in a realistic family/community context. Among the more significant obstacles were those of working within the school organization to create a networked high technology classroom and finding a teacher with the talent and courage not only to tackle the technology, but to make dramatic changes in teaching style in a very short period of time without the benefit of a peer group. We also wished to work with a normal student population whose families would be reasonably representative of a large cross-section of the US population.

The initiation of the project was especially difficult because it began just after the beginning of the 1996-1997 school year; we were concerned that any delay in initiating the program would

mean losing an entire school year. First, the classroom design and renovation had to be done with the children in place. The ergonomics of a constructivist high-tech classroom are more complex than those of a conventional classroom, and the participatory design process we used to create it is discussed in (McCreary, *et al.*, 1998). The project also required a technical support infrastructure both for the teacher and for the families, as well as an extensive evaluation protocol. The evaluation protocol was urgent since our first class had already begun the school year by the time we learned that the project would be supported by the Department of Education. Since the class selection process depended upon IRB approvals at Virginia Tech, class membership had to be changed several weeks into the school year, and the team teaching structure of the 5th-grade class had to be modified so that the students would be close to the technology at all times. Nevertheless, the children viewed their first WWW page within six weeks.

During the first 6 months of the project, Susan, our classroom teacher, was mentored by our master teacher, who had a particularly strong interest in constructivist learning. It was not an easy transition for her, even though Susan had been involved with us in another technology-based project and already had a talent for managing a classroom in which students were exploring independently. However, there was much to learn about the technology, and the constant observation by the project staff and the curiosity of many in the community added another measure of discomfort. Our project approach, however, was that the classroom was Susan's responsibility, and that our role was to build a strong support environment for her in which technical assistance was always available, and she, like her charges, had the same environment at home as at school. To do that we provided her with a technology partner (who, fortuitously, is also a certified teacher) who is freely available to assist with lessons, projects, technology issues, planning, and in-class assistance.

From the outset, we wanted not only to engage the students with the most exciting lessons possible with the technology, but also to tackle some deeper and more difficult objectives. In most general terms, we wanted to lay foundations that would make our children better decision makers in a world of extreme complexity. We wanted them to leave 5th grade more curious than when they entered, and we wanted to emphasize to them that the world is a fascinating place that extends far beyond their classroom or even their community, one that they can learn about just by asking the right questions. We have always been convinced that such deeper changes will be internalized only after longer periods of time. Since attitudes toward inquiry and learning are so closely linked to those of the family, and since most family processes and conventions have evolved over long periods of time, we did not expect fundamental changes to occur quickly. Therefore, this was to be the beginning of a long study in which changes would take several years to emerge. Our hypothesis is that in the long term, family involvement and immersive exposure to technology-supported education will improve both student and family achievement. However, should there be no identifiable long-term changes under these, the best of circumstances, this would call into question some of the basic premises underlying the massive introduction of computing technology into American schools.

In Susan's classroom, there is a computer for every pair of students, which rest on tables of matching color to make the technology as unobtrusive as possible. Computers are treated as accessible learning tools just like crayons and pencils; in the classroom we created the best possible learning environment that we could reasonably provide with the tools and staff at our disposal. Each computer has two multiplexed keyboards but one mouse. Each year we have a new class of 24 students and send a computer home for each family to use indefinitely. We provide free Internet connectivity at home, phone lines for phoneless families, weekly technology training sessions for students and parents, and summer technology classes. On-site technology support is provided free by a support team, and the parents need only make a phone call to report a problem. After 5th

grade, the students attend Auburn Middle School, which is located adjacent to the elementary school.

Getting Started

The Riner community is located about 13 miles south of Blacksburg, Virginia, where Virginia Tech is located. The community is a mixture of Virginia Tech faculty and employees who prefer a more rural lifestyle and rural families who have been in the area for generations. Generally it is a stable community, which is an important consideration in a longitudinal study. Montgomery County itself holds roughly 74,000 residents, and the school district consists of 19 schools attended by some 8,900 students. According to 1990 census figures, 93% of the residents have passed 9th grade, 84.9% have completed high school, and 19.5% of the population is below the poverty line. In 1994-1995, 33% of the children received free or reduced price lunches. At this time 67 of the original 72 children from 63 families remain in the program. Among our families, perhaps 15 have at least one professional parent, and three own businesses; of the remainder, about 7 families farm for primary income with several others doing so part-time. In 1996, Riner Elementary School had three 5th-grade classes from which 24 students were selected by lottery. 100% of the families at Riner returned signed forms indicating a desire to participate in the drawing, at which 9 boys and 15 girls were selected.

Needless to say, at the beginning of the project we were overwhelmed by the need to design the entire project almost overnight. Setting up 40 computers and getting 24 families online was an exhausting task. It began to dawn on us that these families with which we were beginning an intensive relationship represented deep wells of information about internal family dynamics, culture, motivations, attitudes, and beliefs about education. Not only did we have so much contact with them through school, through the parents' program, through meetings, and through interactions about home computing problems, but in most cases the physical computers served to obligate them to interact with us. Therefore, in addition to the increasing volume of survey data we were collecting, we began conducting interviews of all the children and at least one parent of each family to learn more about the family and educational backgrounds, attitudes, relationships with their children, and reactions to the intervention and the new opportunities it was providing. By the end of the first school year we had also obtained a large server through another grant that allowed us to provide our own Email services and to monitor Email and WWW use. We are also implementing our own collaborative applications which we can monitor. An important one is a simple Java-based chat program that is becoming increasingly important in our work; a collaborative text editor is also being implemented. Obligations or not, our families are not always happy about returning survey instruments to us. These require time to complete and effort to return; we suspect that some parents sense that they probe their competencies and feelings of adequacy in mastering the technology and in working actively with their children.

It became clear that life was becoming complicated; many things were happening that we didn't understand. There appeared to be so many external forces that were influencing our children's progress. We found it difficult to account for and interrelate them all and separate technology-related factors from the rest. For example, there were continuing problems with the children failing to return homework, attendance at meetings and parent sessions was lower than we would have liked, and despite the ease of communications that electronic mail afforded, many families seemed unresponsive. We would not get calls from many of the families concerning computing problems until the night before their child would need the computer for an assignment. On the other hand, some children with weak histories of academic performance began to thrive in

the new classroom environment, and some of the best communicators emerged from those children we though least likely to be strong technology adopters. In the first year the principal (who is a grant principal investigator) tended to visit the class frequently; it appears that his interest and his interactions with the children were influential in setting expectations and classroom atmosphere. Clearly our classroom intervention could not be neatly encapsulated and studied in isolation from an extremely complicated school-family-community context, and that made the design, if not the sufficiency of our survey instruments problematic.

Other forces also began to affect our experiment. For example, Virginia formulated a state Standards of Learning document that specified what every child at every grade level should know. The state prepared to put in place a rigorous testing program to enforce school compliance. The resulting changes this has imposed on instructional styles is opposite to the learner-centered exploratory focus of our classroom, and our teacher, Susan is finding it difficult to reconcile the two requirements. Also, the standardized testing program changed so that the Iowa tests we counted on in 7th grade for our first achievement results were abolished. Nevertheless, the children in our classroom grew by leaps and bounds, and the technical competence, pride and self-confidence they displayed as they left for middle school was obvious to everyone. A Stanford 9 test was offered to the 5th graders in the first spring, which we used to compare our children with the other two 5th-grade classes. There were no significant short-term differences; nor had we expected to find any.

Year Two: Evolving Towards a Macroergonomic Research Perspective

In the second year, one of the coauthors, a doctoral student of human factors in Industrial and Systems Engineering at Virginia Tech, joined the PCs for Families project, bringing with her the rigorous quantitative culture of that discipline. That emphasis complements the qualitative studies that provide important insight into family and school dynamics. Her particular interest is in macroergonomics which, in our context, states roughly that learning outcomes result not from isolated stimuli but rather from complicated interactions within a sociotechnical system (STS). Based on that theoretical framework (McCreary and Ehrich, 1999), she has been attempting to identify systematically the key differences between a standard classroom and the PCF classroom and how they relate student and family changes to the PCF intervention.

The STS perspective views the classroom as an organization consisting of a social subsystem, a technical subsystem, an environmental subsystem, and an organizational framework (Hendrick, 1986; Keckley, 1988). All of these components affect educational outcomes, and optimization and measurement has to be done across all of these components simultaneously. One of the pervasive problems with educational research is that so many of the variables are uncontrollable. Macroergonomics provides a framework for classifying these variables and assessing their impact on the larger system. For example, this study is taking place at a time when our school, Riner Elementary, merged with another in a new building and under new leadership, causing a certain amount of disruption to each of the system components. Nevertheless, one needs to identify and characterize the salient variables, measure whatever is observable, and make the best possible deductions about how these variables affect educational outcomes. At the same time, extensive study of the system reveals clues about the system dynamics that enable optimizations to be made.

A major challenge in this approach is that of system identification, namely that of identifying the salient variables, the system components, and their dynamics. At technology conferences one tends to learn primarily about isolated interventions. At the other end of the scale there are no detailed studies of system-wide technology interventions that provide this information in sufficient detail. School superintendents seem to be asking one another about *best practice* in the hope that

out of local studies will come magic bullets that will help them integrate technology in their curricula without making the same mistakes over and over. For researchers, there appear to be three principal options when approaching a completely new classroom paradigm: a) to measure everything possible, b) to formulate a focussed set of hypotheses and associated experiments, or c) to use an evolutionary approach with iterated hypothesize and test cycles. Macroergonomic methodology is a powerful tool for establishing the research agenda by making visible the linkages among the important system variables, thus providing valuable insight for prioritizing measurements and the selection of appropriate evaluation instruments. STS models also provide a theoretical framework for explaining uncovered inter-relationships, such as that between a child's academic orientation and his or her success in a more autonomous constructivist classroom.

We have adopted STS methodology, introducing it in the second year and refining it in this, our third year. We are following an evolutionary approach, continuously reevaluating the interactions among our system components and adding new ones as they are identified. Evolutionary methodology is most viable in a longitudinal study such as ours. As results become available, they suggest new hypotheses; if the STS methodology has been effective, new results follow from reexamination and reinterpretation of the original data. Inevitably new, sometimes obscure, inter-relationships are exposed in the process, and it is still necessary to obtain supplementary data. In the following, we'd like to give some illustrations, using our second-year class as our example.

In 1997, as in the previous year, we again implemented a lottery, and once again, 100% of the families returned signed forms indicating interest in joining the program. This year, however, there were only two 5th-grade classes and a gender-unbalanced subject pool from which 7 girls and 17 boys were selected. Since this is the first year for which complete Email and WWW logs were available, one might begin by asking how extensively students and parents used the Internet. If one asks in surveys or in interviews, the answers are usually quite different from what really happened; near-truth comes from the server logs. For example, no father has ever told us how much he enjoys free access to pornographic sites.

Figure 1 shows Email accesses (that is, the number of times the mailbox was checked for new

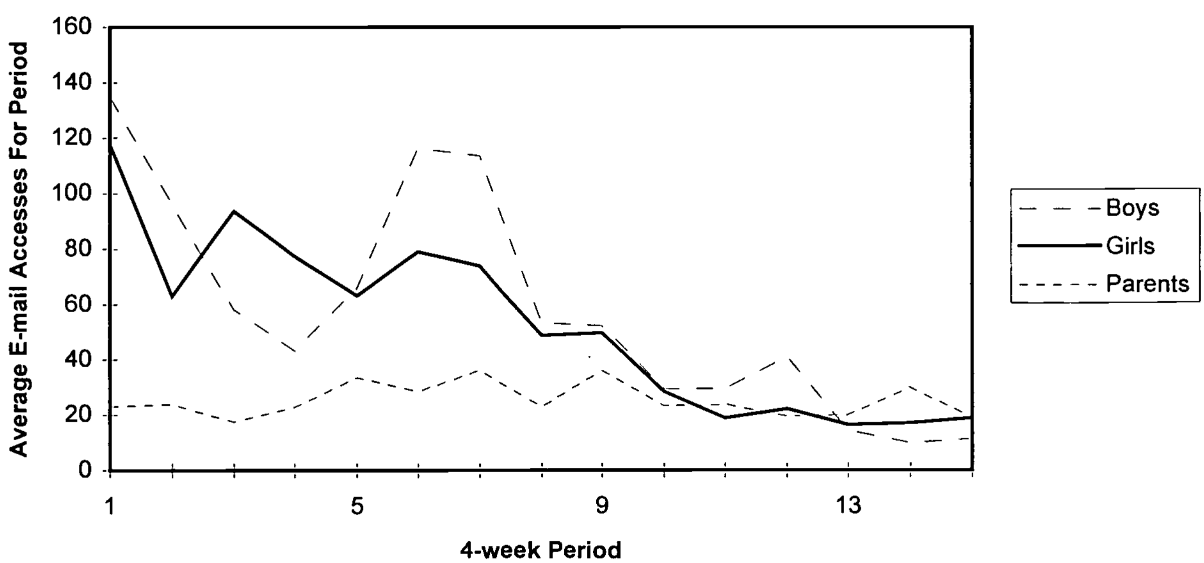

Figure 1 - Class 2 Email accesses.

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mail) by parents and children by gender. Email use is attributable to individuals because there are no shared accounts, while WWW use is total family use, normalized by family size. The first thing one notes is the general decline in activity through the year, which we call the *gee whiz* effect. We speculate that the novelty of network activity wears off as time goes on, until the activity that remains is indicative of the utility of the services to the individual or family at the corresponding points in time. Our data shows remarkable similarity to the Homenet data (Kraut *et al.*, 1996) which gives network access in terms of total connection time. For example, the Homenet data shows a pronounced gee whiz effect in year 1, with teenagers easily dominating adult network use. Similarly, adult use appears to be relatively stable compared with that of the children.

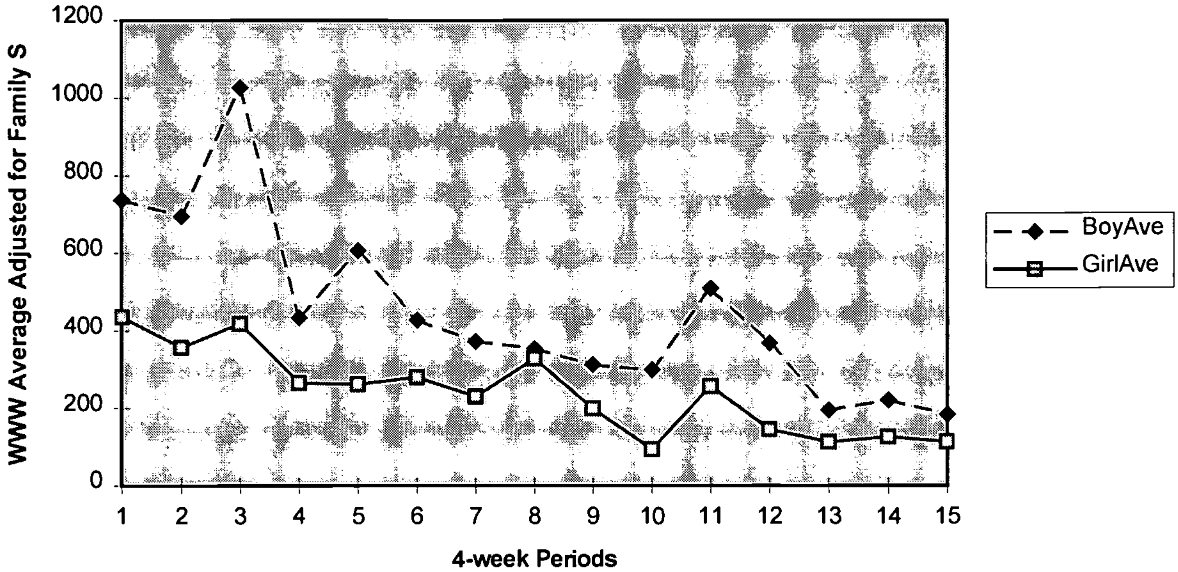

Figure 2 - Family WWW usage by gender of student

Figure 2 again shows the gee whiz effect, but reveals that in WWW usage there is a strong gender effect, also similar to that seen in the Homenet connection data. Interestingly enough one does not see the strong gender differentiation in Email use. To construct hypotheses that explain these observations one needs to know more about the nature of this particular class.

It needs to be emphasized that it is unusual to select a classroom as we did by random lottery, but we felt that for at least two years we should continue with completely random selection, since the children in our classes represented a broad spectrum of backgrounds and capabilities. At the first lottery we noted that several families were not in attendance; so that the missing families would still have the opportunity to join our project, the principal decided to draw for them. At the second lottery, even fewer families attended the drawing, so once again the principal drew for them. During the second year we also had decreasing family attendance at obligatory meetings and problems getting surveys returned. Lacking explanations, we began to think that the novelty of the PCF program might simply be wearing off.

Among the second-year children were 6 to 8 boys who were disruptive and difficult to engage academically; the girls, on the other hand, were generally overachievers. Since the boys required far more than their share of the teachers' attention, the girls were openly resentful of the attitudes of the boys. During class the boys would become disinterested, leave their desk, and walk

around the classroom unless a teacher was specifically working with them. They responded most to visual images and WWW graphics, while the girls tended to enjoy written materials and written communications. As a result, our second class learned and accomplished far less than either of our other two classes. While this was a trying experience for Susan, our teacher, we have learned a great deal from this group of families.

It would be too simple to conclude that the classroom technology or the way it was applied was ineffective in engaging our second-year boys; on the contrary, the middle school teachers seem impressed by their preparation and their willingness to mentor their less technically experienced 6^{th}-grade classmates. Rather, our sociotechnical system methodology leads us to suspect a complex network of links. Let's examine some of the clues.

First, in this year the school principal moved to another school as Riner Elementary School prepared to merge with another school in a new building. The temporary principals (one for each half of the school year) no longer visited the classroom or provided Susan with adequate disciplinary support until a turning point that came when the boys damaged computer monitors with permanent magnets. Second, it appears that the social relationships among these particular boys encouraged behaviors that probably would not have been seen in isolation. Also factoring heavily into events are family dynamics and family-school relationships. Because of job stress (Smrekar, 1996), literacy levels, or other factors, the particular families involved tended not to provide strong support structures for their children. Since these children had never experienced a constructivist classroom before, the classroom structure they relied on decreased due to the independence and self-direction that this learning style assumes. Several parents showed negative attitudes toward education, lack of interest in what their children were doing, and even belligerence when approached by the staff over performance or disciplinary issues. A number of families would not report computing problems until assignments that relied on the equipment were due. Then the parents would use these problems as excuses for their children's failure. In fact, in some families the power structure seemed to be inverted, with the parents generally capitulating to their children.

Given this family context we found it notable in our interviews that almost without exception the parents would emphasize the importance of their child's education, in contrast to the reticence one often finds among Appalachian parents to support achievement among their children that exceeds their own. They had nothing but praise for the PCs for Families program and emphasized their good fortune to have been selected. However, we began to see that some of the families had insecurities about their parental roles, or perhaps lack of knowledge, capability, or persistence to deal with the constant demands of parenting. At this point we realized that we needed to change the nature of the parents' evening program to focus more on helping the parents understand how to work with their children in the context of the technology we were providing. We now have them bring their children with them frequently, and both we and they have been extremely pleased with the results of joint learning and exploration.

As a result of these experiences we are beginning to focus more on the relationship between family dynamics and the children's learning with technology. Given our extensive data we can now partition our children according to various characteristics to look for correlations between learning and family characteristics. Of particular interest to us are the effects of job stress and literacy. A number of our parents have multiple jobs or work multiple shifts, and their survival needs impact their ability to spend time with their children. At the parent sessions we also note that although almost all can read and write, perhaps a third can barely find the keys on the keyboard. The children become frustrated with their parents' ability levels, and their joint activities have to take into account the much faster learning rates of the children.

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Another statistically significant result is that the families perceive their efforts to work with their children as increasing as they year progresses, while the children's perception is just the opposite, that the parents' involvement is decreasing. Again, this may be attributable to the differences in learning rates between the parents and their children; as training progresses, the parents often have increasing difficulty with the technology, while the children absorb new ideas with much less difficulty.

This fall the network logs showed that 15 of 21 first year students (the incoming 7th-graders) are regularly checking their Email and that 18 of 22 second year students (the incoming 6th-graders) are doing so. The parents, however, are not all reliable communicators, and we see evidence of what communication theorists term *critical mass theory* (Markus, 1987). Critical mass theory posits that adoption of a new communication technology depends exactly on the reachable community and value perceived by the potential adopters. Interactive media such as Email are vulnerable to startup/adoption problems, especially when either the reachable community is too small, when the perceived gains from access are low, or when it is not in the adopter's self-interest to become accessible. Thus, families with members in remote locations would be likely to adopt Email quickly, while those which are largely local might complain that the technology was too complicated and forget how it works as soon as they leave the classroom. Since we have all the log files, we can identify the adopting and non-adopting families and design the next round of interview protocols to probe for the reasons.

A possible explanation that emerges for our second-year experiences is that at least at the outset, the values and objectives of the program were not a good match with those of some of the families. Not knowing what was to come, these families may have joined the program anyway, thinking that by signing a form they had an opportunity to acquire a computer. However, these families will be among the more interesting ones to study in the long term since their potential gains may be greater than for those who started the program aligned with its objectives.

More Linkages

Over the past two years, our classroom has had many significant success stories, though it is difficult to find common reasons. Some children with difficult family circumstances found through networked communication a new and vital link to social relationships outside their families. Others who were academically disconnected found themselves able to master new concepts and processes and found new self-worth through their successes. Others were able to improve reading or writing skills, and many of the most talented students just absorbed everything we had to offer.

Sandra, Patricia, Susan, and Sam (not their real names) are typical of a small number of children in our classes whose family circumstances are especially difficult or who are physically isolated from the community because of a lack of transportation. These are children with many reasons to fail but who, for some reason found in networked computing new ways to reach out to others in their community to establish links that have helped them cope with their circumstances and succeed. Patricia, for example, became a class leader, always trying out new ideas and getting others to join in. We were so excited by her enthusiasm and were saddened when her mother decided to move from the area, leaving her computer lifeline behind. Sandra found, besides the communications links afforded by Email, a relationship with a role model that has endured long after 5th grade. And then there is Sam, another communicator who is reaching out for friendship and community.

In addition to meager outlets for after-school social needs, Sandra, Patricia, Susan, and Sam share an ability to communicate using written expression and above average language scores on

standardized tests. However, how they utilize the network technology is very different. Sandra, Patricia, and Susan frequently use the technology to connect with their fellow students, teachers, and individuals in the larger global community, while Sam primarily uses it to contact his fellow students after-school and is unresponsive to teacher attempts to engage him in conversations through Email or chat. Interestingly, unlike the girls who are avid communicators both in person and on-line, Sam seldom initiates face-to-face communication at school, instead preferring mediums which allow him to communicate from a distance after-school. Sam is also unique in his concoction of elaborate on-line story adventures. He plays out his fantasies and simulates conversations between characters by logging on to the chat facility under different names. He sometimes enlists other male students to take part in his on-line adventures.

Many of our other children are socially quite active through church groups, sports, and other activities; these children seem to rely less on their technology than Sandra, Patricia, Susan, and Sam. Kraut has already observed in a well-known paper (Kraut, *et al.* 1998) that there is a significant correlation between the extent of network use and feelings of isolation or depression. Our observations of a number of our children are consistent with his, and we need to explore this more fully. We also have preliminary indications from analysis of our chat logs that adoption of this mode of communication correlates with third-grade literacy. Again, we plan to pursue this more intensively and determine whether the same is true for Email use.

Another comment we hear over and over again as we interview our families is that the transition to a regular 6th-grade class in middle school has been difficult. In addition to the normal changes that occur at this time, the children have reacted to the change back from a constructivist classroom to a conventional style, a perceived lack of value among teachers and peers of the technical skills they learned, and a new community in which many new friends have no Internet access. Auburn Middle School has only a single 17-seat computer laboratory, and only five classrooms have a networked computer. With such limited facilities and teachers not strongly engaged in technology-supported pedagogy, the students failed to receive the reinforcement they needed at school for the tools and methodologies they had adopted.

During the second project year we began to work with the middle school teachers to help them integrate the available technology into their curriculum. However, these ongoing efforts are in their infancy, and our graduates are largely responsible for applying their own computing tools and computing knowledge to their middle school academic work. Thus, after 5th grade, there is little direct pressure for the families to continue using networked computing, and the extent to which they do will be an indication of the value that the families associate with their new tools. We have nevertheless learned how important it is that the children receive continued reinforcement of that which they have learned during the 5th-grade intervention. In families with a strong support structure this is less important, but many other children rely on the stability and continuity provided by their school.

Conclusions

Dramatic changes are taking place in our families as they respond to the challenges we have placed before them. These are long-term changes, and their nature is determined by complex influences of existing cultures, values, attitudes, competencies, self-esteem, communities, and resources (such as time). The networked computers are only catalysts for change; the family responses are determined largely by these factors. We hope that STS methodology will help us determine where significant changes are taking place and that our ethnological studies will explain the mechanisms. As for the deeper effects of our efforts on the children, these will be determined in

time. We are observing in our results, correlations with other investigations such as the Homenet project, with Smrekar's work on family commitment, and with other theories such as critical mass theory that bear on the dynamics of technology adoption.

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